

**We claim:**

1           1.    A method for transferring data between a central  
2   controller and a first node of a plurality of remote  
3   network nodes over a digital data network having a passive  
4   optical network topology, the network connecting the  
5   central controller and the plurality of remote network  
6   nodes, the method comprising the steps of:

7           discovering the first node by the central controller;  
8           synchronizing the internal clock of the first node to  
9   the internal clock of the central controller; and

10          transmitting uplink data from the first node to the  
11   central controller in response to transmission  
12   authorizations sent by the central controller to the first  
13   node.

1           2.    A method for transferring data according to  
2   claim 1, further comprising the steps of:

3           measuring round trip delay from the central  
4   controller to the first node; and

5           transmitting downlink data from the central  
6   controller to the first node.

1           3.    A method for transferring data according to  
2   claim 2, further comprising the step of encrypting the  
3   downlink data.

1           4.    A method for transferring data according to  
2   claim 3, further comprising the step of the first node  
3   sending an encryption key to the central controller,  
4   wherein the step of encrypting the downlink data comprises  
5   the step of encrypting the downlink data with the  
6   encryption key.

1           5.    A method for transferring data according to  
2   claim 3, further comprising the step of the first node  
3   periodically sending a different encryption key to the  
4   central controller, wherein the step of encrypting the  
5   downlink data comprises the step of encrypting the  
6   downlink data with the encryption key last received by the  
7   central controller from the first node.

1           6.    A method for transferring data according to  
2   claim 3, further comprising the step of detecting, by the  
3   central controller, connection failure between the central  
4   controller and the first node.

1        7. A method for transferring data according to  
2 claim 6, further comprising the step of detecting, by the  
3 first node, connection failure between the central  
4 controller and the first node.

1        8. A method for transferring data according to  
2 claim 3, wherein the downlink data and the uplink data  
3 are transmitted using IEEE 802.3 Ethernet standard  
4 packets.

1        9. A method for transferring data according to  
2 claim 8, wherein the network is a passive optical network.

1        10. A method of transferring data according to claim  
2 2, wherein the steps of discovering and synchronizing  
3 comprise the steps of:

4        sending a GATE message from the central controller to  
5 undiscovered nodes, said GATE message sent to the  
6 undiscovered nodes comprising a time stamp of the central  
7 controller, a first grant start time value, a first grant  
8 length value, and a first GATE message MAC control opcode;

9        receiving at the first node the GATE message  
10 addressed to the undiscovered nodes;

11        setting the internal clock of the first node to the  
12        time stamp of the GATE message addressed to the  
13        undiscovered nodes;

14        after the setting step, sending a REGISTER\_REQUEST  
15        message from the first node to the central controller  
16        between the time when the internal clock of the first node  
17        equals the first grant start time value and the time when  
18        the internal clock of the first node equals to the sum of  
19        the first grant start time value and the first grant  
20        length value, the REGISTER\_REQUEST message comprising a  
21        time stamp of the first node, address of the first node,  
22        and a REGISTER\_REQUEST message MAC control opcode;

23        in response to receiving the REGISTER\_REQUEST message  
24        at the central controller, sending a REGISTER message to  
25        the address of the first node, the REGISTER message  
26        comprising a REGISTER message MAC control opcode.

1        11. A method of transferring data according to claim  
2        10, wherein the step of transmitting uplink data comprises  
3        the steps of:

4        sending the transmission authorizations to the  
5        address of the first node, the transmission authorizations

6 comprising a plurality of GATE messages sent to the  
7 address of the first node, each GATE message of the  
8 plurality of GATE messages sent to the address of the  
9 first node comprising a second GATE message MAC control  
10 opcode and at least one pair of one grant start time value  
11 and one grant length value, each said pair defining one  
12 allowable uplink transmission interval;

13 sending the uplink data from the first node to the  
14 central controller in response to receiving a GATE message  
15 at the first node, each packet of the uplink data being  
16 transmitted during an allowable uplink transmission  
17 interval.

1 12. A method of transferring data according to  
2 claim 11, wherein at least one GATE message of the  
3 plurality of GATE messages sent to the address of the  
4 first node comprises at least two pairs of one grant start  
5 time value and one grant length value.

1 13. A method of transferring data according to claim  
2 11, wherein the step of measuring round trip delay  
3 comprises the step of subtracting a first time stamp of  
4 the first node in a first message received by the central  
5 controller from the value of the real time clock of the

6 central controller at the time the first message is  
7 received.

1 14. A method of transferring data according to claim  
2 13, further comprising the steps of:

3 sending an encryption key from the first node to the  
4 central controller; and

5 encrypting the downlink data transmitted by the  
6 central controller to the address of the first node using  
7 the encryption key.

1 15. A method of transferring data according to claim  
2 14, wherein the downlink data is transmitted in packets,  
3 each packet comprising a header and a payload, wherein  
4 encrypting the downlink data comprises the step for block  
5 encrypting the payload of said each packet.

6 16. A method of transferring data according to claim  
7 13, further comprising the steps of:

8 the central controller sending a request for an  
9 encryption key to the first node;

10 sending an encryption key from the first node to the  
11 central controller in response to the request for an  
12 encryption key; and

13 encrypting the downlink data transmitted by the  
14 central controller to the address of the first node using  
15 the encryption key.

1 17. A method of transferring data according to claim  
2 14, wherein the step of sending an encryption key  
3 comprises the step of sending a NEW\_KEY message from the  
4 first node to the central controller, the NEW\_KEY message  
5 comprising the address of the first node, a NEW\_KEY  
6 message MAC control opcode, the encryption key, and an  
7 identifier of the encryption key.

1 18. A method of transferring data according to claim  
2 17, wherein the downlink data is sent in packets, each  
3 packet comprising a header that comprises the identifier  
4 of the encryption key used to encrypt the packet.

1 19. A method of transferring data according to claim  
2 13, further comprising the steps of:

3 periodically sending a different encryption key from  
4 the first node to the central controller;

5        encrypting the downlink data transmitted by the  
6        central controller to the address of the first node using  
7        the last received encryption key.

1        20. A method of transferring data according to claim  
2        19, wherein:

3        the step of periodically sending a different  
4        encryption key comprises the step of periodically sending  
5        a different NEW\_KEY message from the first node to the  
6        central controller, each NEW\_KEY message comprising the  
7        address of the first node, a NEW\_KEY message MAC control  
8        opcode, an encryption key, and the sequence number of the  
9        encryption key comprised in said each NEW\_KEY message, the  
10       step of periodically sending a different NEW\_KEY message  
11       comprising the step of sending a first NEW\_KEY message  
12       comprising a first encryption key and a first sequence  
13       number corresponding to the first encryption key;

14       the downlink data is sent in packets, each packet  
15       comprising a header that comprises the sequence number of  
16       the encryption key used to encrypt the packet;

17       the method further comprising the steps of:



18 monitoring the sequence numbers in the headers of the  
19 downlink packets sent to the address of the first node;  
20 and

21 re-sending the first NEW\_KEY message to the central  
22 controller if none of the monitored sequence numbers  
23 matches the first sequence number within a first  
24 predetermined time period.

1 21. A method of transferring data according to claim  
2 13, wherein the downlink data and the uplink data are  
3 transmitted using IEEE 802.3 Ethernet standard packets.

1 22. A method for transferring data according to  
2 claim 21, wherein the network is a passive optical  
3 network.

1 23. A method for transferring data according to  
2 claim 22, wherein

3 the step of transmitting uplink data further  
4 comprises the step of the first node transmitting REPORT  
5 messages to the central controller, each REPORT message  
6 comprising the address of the first node, at least one  
7 request for uplink transmission of a first number of bytes

8 from a queue of the first node, and a REPORT message MAC  
9 control opcode; and

10 the central controller sends the GATE messages of the  
11 plurality of GATE messages sent to the address of the  
12 first node in response to receiving the REPORT messages.

1 24. A method for transferring data according to  
2 claim 23, wherein said each REPORT message further  
3 comprises a priority indication of the queue.

1 25. A method for transferring data according to  
2 claim 23, further comprising the step of detecting  
3 connection failure between the central controller and the  
4 first node.

1 26. A method for transferring data according to  
2 claim 25, wherein the step of detecting connection failure  
3 comprises the steps of:

4 resetting a first timer at the central controller  
5 each time a REPORT message is received from the first  
6 node; and

7 discontinuing sending of the GATE messages to the  
8 address of the first node if the first timer reaches a  
9 first timeout value.

27. A method for transferring data according to claim 26, wherein the step of detecting connection failure further comprises the steps of:

resetting a second timer at the first node each time a GATE message sent to the address of the first node is received at the first node;

if the second timer reaches a second timer timeout value, repeating the steps of discovering and synchronizing.

28. A method for transferring data between an optical line terminal (OLT) and a first optical network unit (ONU) of a plurality of ONUs over a passive optical network, the method comprising the steps of:

the first ONU receiving a GATE message addressed to undiscovered nodes, the GATE message comprising a time stamp of the OLT, a first grant start time value, a first grant length value, and a GATE message MAC control opcode;

setting the internal real time clock of the first ONU to the time stamp of the OLT;

after the setting step, sending a REGISTER\_REQUEST message from the first ONU to the OLT during the time

13 interval defined by the first grant start time value and  
14 the sum of the first grant start value and the first grant  
15 length value, the REGISTER\_REQUEST message comprising a  
16 time stamp of the first ONU, the address of the first ONU,  
17 and a REGISTER\_REQUEST message MAC control opcode;

18 receiving a REGISTER message addressed to the address  
19 of the first ONU, the REGISTER message comprising a  
20 REGISTER message MAC control opcode;

21 receiving GATE messages addressed to the address of  
22 the first ONU, each received GATE message comprising the  
23 GATE message MAC control opcode and one or more  
24 definitions of allowed uplink transmission intervals; and

25 sending uplink data packets from the first ONU to the  
26 OLT only during the allowed transmission intervals.

1 29. A method for transferring data according to  
2 claim 28, wherein the REGISTER\_REQUEST message is sent  
3 beginning at a random time  $T_r$  uniformly distributed within  
4 the time period beginning with the first grant start time  
5 value and ending with  $T_e = (\text{the first grant start time}$   
6  $\text{value}) + (\text{the first grant length value}) - (T_1)$ , where  $T_1$  is  
7 equal to the length of the REGISTER\_REQUEST message.

1        30. A method for transferring data according to  
2 claim 28, further comprising the steps of:

3        sending a first encryption key and a first sequence  
4 number of the first encryption key from the first ONU to  
5 the OLT, to enable the OLT to encrypt downlink data  
6 packets addressed to the address of the first ONU with the  
7 encryption key.

1        31. A method for transferring data according to  
2 claim 30, further comprising the steps of:

3        receiving, at the first ONU, the downlink data  
4 packets addressed to the address of the first ONU, each  
5 downlink data packet comprising a header comprising the  
6 sequence number of the key used in encrypting said each  
7 downlink data packet;

8        monitoring, at the first ONU, the sequence numbers in  
9 the headers of the received downlink data packets;

10       if none of the sequence numbers in the headers of the  
11 downlink data packets received within a first  
12 predetermined period matches the first sequence number,  
13 re-sending the first encryption key and the first sequence  
14 number from the first ONU to the OLT.

1        32. A method for transferring data according to  
2 claim 31, wherein the downlink data packets and the uplink  
3 data packets conform to the IEEE 802.3 Ethernet standard.

1        33. A method for transferring data according to  
2 claim 32, further comprising the step of periodically  
3 sending REPORT messages from the first ONU to the OLT,  
4 each said REPORT message requesting allocation of one or  
5 more time intervals for transmission of the uplink data  
6 packets from the first ONU to the OLT.

1        34. A method for transferring data according to  
2 claim 32, further comprising the steps of:

3        the first ONU detecting failure of connection between  
4 the first ONU and the OLT; and

5        after detecting failure of connection between the  
6 first ONU and the OLT, the first ONU repeating, in order,  
7 the steps of receiving a GATE message addressed to  
8 undiscovered nodes, setting the internal real time clock  
9 of the first ONU, sending a REGISTER\_REQUEST message from  
10 the first ONU to the OLT, and receiving a REGISTER message  
11 addressed to the address of the first ONU.

35. A method for transferring data between an optical line terminal (OLT) and a first optical network unit (ONU) of a plurality of ONUs over a passive optical network, the method comprising the steps of:

sending a first GATE message from the OLT to undiscovered ONUs, the first GATE message comprising a time stamp of the OLT, a first grant start time value, a first grant length value, and a first GATE message MAC control opcode;

receiving at the OLT a REGISTER\_REQUEST message from the first ONU, the REGISTER\_REQUEST message comprising a time stamp of the first ONU, an address of the first ONU, and a REGISTER\_REQUEST message MAC control opcode;

in response to receiving the REGISTER\_REQUEST message, sending from the OLT a REGISTER message to the address of the first ONU, the REGISTER message comprising a REGISTER message MAC control opcode;

periodically sending GATE messages to the address of the first ONU, each said GATE message sent to the address of the first ONU comprising the GATE message MAC control opcode and at least one pair of one grant start time value

22 and one grant length value, each said pair defining a time  
23 interval during which the first ONU is allowed to send  
24 messages to the OLT; and

25 receiving uplink data packets from the first ONU in  
26 the time intervals during which the first ONU is allowed  
27 to send messages to the OLT.

1 36. A method for transferring data according to  
2 claim 35, further comprising the steps of:

3 receiving, at the OLT, an encryption key sent by the  
4 first ONU; and

5 sending, from the OLT to the first ONU, downlink data  
6 packets encrypted with the key.

1 37. A method for transferring data according to  
2 claim 36, further comprising the step of measuring round  
3 trip delay between the OLT and the first ONU by  
4 subtracting a first time stamp of the first ONU comprised  
5 in a first message received by the OLT from the first ONU  
6 from the value of the internal clock of the OLT at the  
7 time the first message is received by the OLT.



1        38. A method for transferring data according to  
2 claim 36, wherein the downlink and uplink data packets are  
3 transmitted using IEEE 802.3 Ethernet standard.

1        39. A method for transferring data according to  
2 claim 38, further comprising the step of:

3        receiving REPORT messages from the first ONU, each  
4 REPORT message received from the first ONU comprising at  
5 least one request for uplink transmission of a first  
6 number of bytes;

7        wherein the OLT sends the GATE messages to the  
8 address of the first ONU in response to the received  
9 REPORT messages.

1        40. A method for transferring data according to  
2 claim 39, further comprising the steps of:

3        resetting a first timer at the OLT each time a REPORT  
4 message is received from the first ONU; and

5        discontinuing sending of the GATE messages to the  
6 address of the first ONU if the first timer reaches a  
7 first timeout value.